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R. W. Brainard and R. H. Marshall

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NORTH AMERICAN AVIATION, INC.

COLUMBUS DIVISION COLUMBUS 16, OHIO

ENGINEERING DEPARTMENT

RESOLUTION REQUIREMENTS FOR IDENTIFICATION OF TARGETS IN TELEVISION IMAGERY

(RDA's 1852 and 2029)

PREPARED BY

R. W. Brainard, Project Engineer
Information Sciences

E. C. Hanford, Sr. Res. Eng.
Missile Systems

R. H. Marshall, Sr. Operations Res. Analyst
Weapon System Analysis

APPROVED BY

G. N. Ornstein, Chief Scientist
Information Sciences

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ABSTRACT

The purpose of this study was to empirically relate the probability of correctly identifying targets in television imagery to the number of scanning lines traversing the target. Five different targets (scaled models) were investigated: an aircraft, oil storage tanks, a bridge and two buildings. Each target was located in different positions and orientations on a scaled terrain model. A television system scanned the terrain model and presented the image on a monitor. Observers attempted to identify which one of the five targets was located within a small, inscribed area.

Results indicated that for each of the five targets, identification was approximately a linear function of the number of scanning lines traversing the target. The functional relationships were highly similar, in spite of the considerable differences in the size and shapes of the five targets.

This research was conducted under RDA 1852 (90 percent) and RDA 2029 (10 percent).

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INTRODUCTION

The human is frequently required to identify targets in television imagery. Various factors influence the identifiability of targets, but none is of greater significance than the quality of the imagery. Image quality is itself determined by various factors, some of which are external to the television system such as atmospherics, and others which arise from the inherent characteristics of the television system.

Restricting our consideration to those factors inherent with the system, the quality of a television image is determined principally by three factors: the signal-to-noise level, the system bandwidth and the number of scanning lines. Of course, brightness and contrast influences image quality but these are readily modifiable over a wide range in a given system. These three preceeding factors are fundamental in that they derive from the inherent characteristics of the system and are unmodifiable for a given system.

The purpose of the present study was to investigate the effects of one of these fundamental factors -- the number of scanning lines -- upon target identification. Specifically, the objective was to empirically relate the number of scanning lines which traverse a target to the probability of correctly identifying that target.

STUDY DESIGN

APPARATUS

The North American Aviation, Inc. Visual Presentation Simulator was used in this study. This facility, as used in the present study, consisted of a television camera, mounted on a mobile rig, which scanned a terrain model and displayed the image on a television monitor. The camera and rig were programmed (via analogue computer) so as to "fly" a specific course over the terrain model. Throughout the flight, the (dynamic) image of the area of the terrain model being viewed by the camera was continuously displayed on the monitor. The major components of the facility are described below.

Terrain Model

The model was constructed to a scale of 1:3000, and measured 8 x 20 feet. The construction of the model was based upon the modeling techniques developed at the Ohio State University (Blackwell, et al, 1961). A photograph showing a portion of the model is presented in Figure 1. The model, mounted on a wall with the eight-foot dimension oriented vertically, was illuminated by a bank of flourescent lamps which provided bright, diffuse lighting.

Television System

The television camera was a Diamond Electronic Company Model 500. The camera was equipped with a Wollensak 1", f 1.5 Cine Raptar lens which was set to f 5.6 and focused at three feet. The camera was

Figure I
Photograph of Terrain Model

mounted on a servo-driven rig which provided six degrees of freedom: x, y and z rectilinear motion plus roll, pitch and yaw.

The monitor used for displaying the image of the terrain model (obtained by the television camera) was a Conrac Television Company Model CF 17-C. An example of a displayed image is presented in Figure 2. The observers were seated 27 inches from the face of the monitor. A switch mounted beside the observer was used to signal the point at which the target was identified. The switch acted to stop the motion of the camera rig; the elapsed viewing time and the slant range between the camera lens and the "impact" point on the terrain model were recorded at the time of identification.

The vertical resolution of the system was measured using a fan-shaped resolution pattern consisting of alternating black-and-white elements. A linear scale, numbered from 1 to 5 with half unit indexing marks, was placed along the side of the resolution pattern. The ensemble was placed on the terrain model oriented perpendicularily to the line of sight and at the center of the field of view. The TV camera was then located at various discrete distances from the resolution pattern; at each position setting, five observers independently indicated the point on the resolution pattern at which the black-and-white elements could just be resolved. The observer indicated his judgment of the resolution by referring to the corresponding value on the linear scale. The latter values were subsequently converted by the scale factor of the

Figure 2
Photograph of Displayed Image

terrain model to ground resolution (the width of a single black or white resolution pattern element) normal to the line-of-sight. The values obtained from each of the five observers, and the mean values, are presented as a function of slant range in Figure 3. (The resolution degradation which occurs at the short slant ranges is due to the camera becoming defocused.)

Analog Computer

A Pace analog computer was mechanized to provide a 15° ramp "flight path" for the television camera rig, with selectable initial x and y coordinates. The initial simulated slant range and altitude in each case were 22,500 feet and 5,800 feet respectively. The simulated airspeed was 600 feet per second.

TARGETS

The five different types of targets investigated in this study were: an airplane, a bridge, two oil storage tanks, a rectangular-shaped building and an "L-shaped" building. The dimensions (simulated) of the targets are presented in Table 1.

All targets were painted a dull silver.

The targets were placed at different positions on the terrain model, and in different orientations. The brightness of the target and its immediate background for each of the different positions was measured from the television monitor by a Spectra Brightness Meter (marketed by the Photo Research Corp.). Since the brightness of the target (and its immediate background) was generally nonhomogeneous,

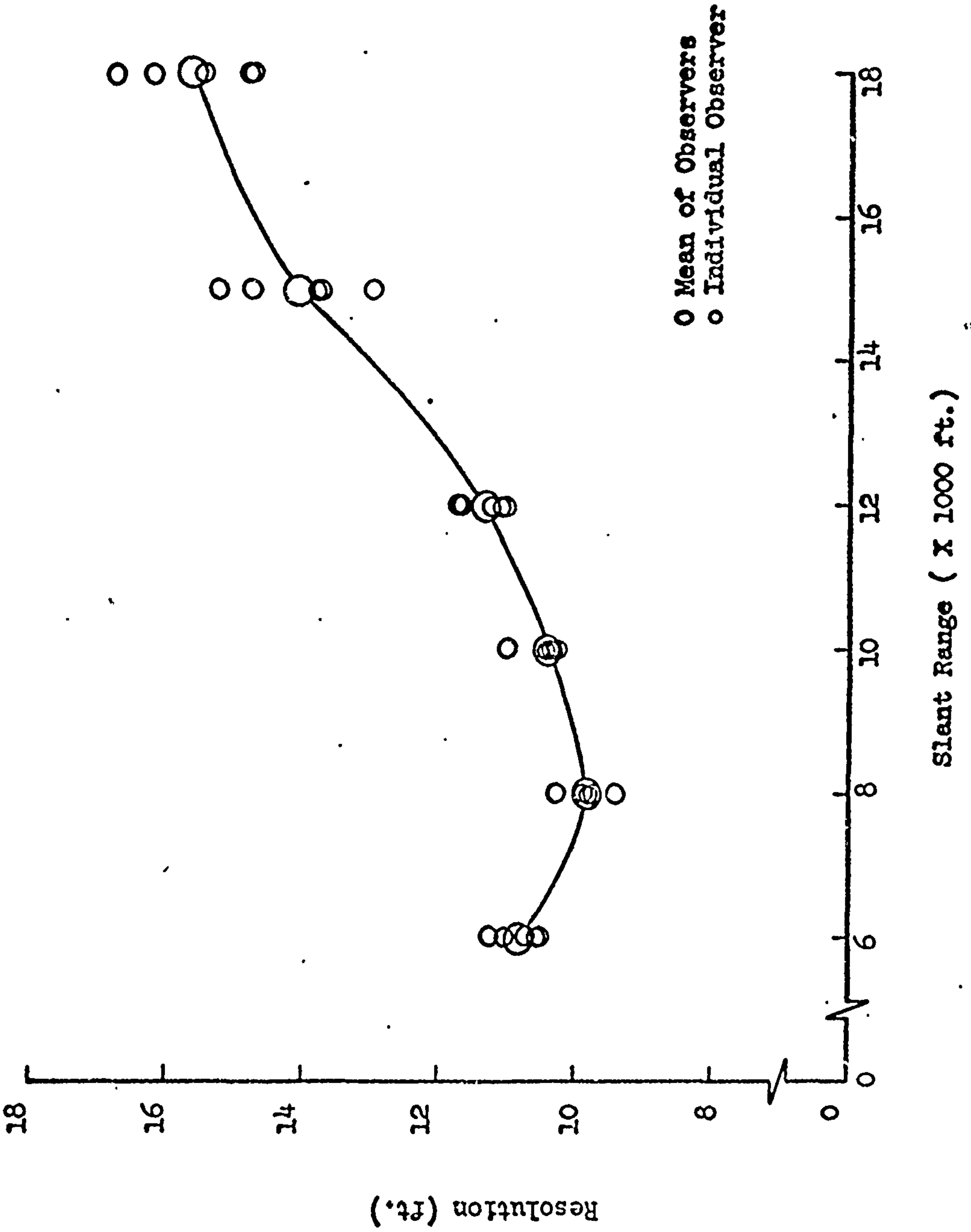

Figure 3

System Resolution

Table 1

Target Dimensions

Target	Dimensions (ft.)	
Airplane	Wing Span	150
	Length	200
Oil Storage Tanks	Height	35
	Diameter	102
	Space between Tanks	100
Bridge	Height (max.)	70
	Length	317
	Width	55
Building, L-Shaped (L)	Height	27
	Length (large wing)	227
	Width (large wing)	62
	Length (small wing)	153
	Width (small wing)	66
Building, Rectangular (R)	Height	28
	Length	218
	Width	76

readings were taken from a number of areas within the target (and its immediate background) and a mean value was computed. These values were then used to compute the target-background contrast, C, which was defined as,

$$C = \frac{\bar{B}_T - \bar{B}_B}{\bar{B}_B}$$

where $\bar{B}_T$ is the mean brightness of the target and $\bar{B}_B$ is the mean brightness of the background.

The target orientation is specified with respect to the longitudinal axis of the target, i.e., the longest axis of the target or target complex.

The data (target-background contrast and target orientation) are presented in Table 2.

Table 2

Target-background Contrast and Target Orientation

Location	Target	Orientation	$\bar{B}_T$	$\bar{B}_B$	C
1	Aircraft	320	2.30	1.20	.92
2	Building (L)	180	2.20	1.37	.61
3	Bridge	120	3.10	1.75	.77
4	Oil Tanks	90	3.75	2.05	.83
5	Building (L)	220	1.90	1.10	.61
6	Building (L)	75	1.70	1.10	.55
7	Building (R)	35	1.53	1.30	.18
8	Building (R)	150	2.75	1.17	1.35
9	Bridge	45	2.10	1.53	.37
10	Building (L)	0	2.30	1.20	.92
11	Oil Tanks	90	2.20	1.37	.61
12	Building (R)	120	3.10	1.75	.77
13	Aircraft	30	1.77	1.10	.61
14	Bridge	155	1.70	1.10	.55
15	Building (R)	90	3.75	2.05	.83
16	Building (R)	45	2.10	1.53	.37
17	Oil Tanks	140	2.75	1.17	1.35
18	Aircraft	270	1.53	1.30	.18

IDENTIFICATION TASK

A total of 18 target-location combinations were investigated. The airplane, oil storage tanks and bridge targets were each investigated in three different locations, the L-shaped building was investigated in

four combinations and the rectangular building in five combinations. The 18 combinations were randomized in their order of occurrence to the observers; the random order of combinations, number 1-18, is presented in Table 2. One-half of the observers had the sequence of 1-18 while the other half had the sequence of 10-18 followed by 1-9.

With each combination the slant path of the camera was chosen so that the target occurred precisely at the center of the monitor over the entire course of the path. The target and its immediate surround were enclosed in a 1.5 inch circle enscribed on the face of the television monitor.

Each observer was given photographs of the targets for study and familiarization before commencing the data collection; the observer could refer to the photographs at any time during the data collection period. The observers were told that one of the five targets would appear within the enscribed circle and that his task was to decide which one of the five targets was present.

The rig on which the television camera was mounted was then started on its "flight path" and continued at a constant velocity until the observer made an identification response. If a response was not made before reaching a slant range of 2300 feet, the rig was automatically stopped. The observers were told to identify the target as soon as possible, without making more than 5 percent incorrect

identifications. In each instance, the observer was told the true identity of the target following his identification response.

A total of 10 NAA personnel were used as observers.

RESULTS

The percentage of correct and incorrect target identification responses and omissions (failures to respond) for each type of target is presented in Table 3.

Table 3

Percent Correct and Incorrect Target Identifications and Omissions

Target	Percent Correct	Percent Incorrect	Percent Omissions
Aircraft	83.3	6.7	10.0
Oil Storage Tanks	93.3	0.0	6.7
Bridge	100.0	0.0	0.0
Building (L)	75.0	25.0	0.0
Building (R)	84.0	16.0	0.0
Mean	87.1	9.5	3.3

The slant ranges at which identification responses were made by each observer are presented in Appendix A. The mean slant range, and standard deviation, at which correct identification occurred is presented in Table 4 for each target type. The variability of the slant ranges, expressed by the standard deviation, are relatively large. This variability arises from the different target locations and the

Table 4

Mean Slant Range and Standard Deviation at Target Identification

Target	Mean Slant Range	Standard Deviation of Slant Range
Aircraft	8613	2811
Oil Storage Tank	11714	3780
Bridge	10731	3629
Building (L)	9607	2268
Building (R)	9030	2662

different observers. An analysis of the variability (variance) indicated that the variability associated with the aircraft, oil storage tanks and the bridge targets was due primarily to the differences among the observers. However, the variability associated with the building targets was about equally attributable to differences among observers and target positions.

The mean slant range at target identification was plotted as a function of the target-background contrast, and as a function of the target orientation. An examination of these two plots, which are presented in Appendix B, failed to show any consistent relationship between either of the two factors and the identification slant range.

A comparison of the slant ranges at which the correct and incorrect responses were made indicated that the latter generally occurred at ranges which were either significantly longer, or significantly shorter, than the mean range at which correct responses were made. The incorrect responses made at the "long" and "short" ranges occurred at an average distance of 12,476 and 6,130 feet, respectively, as compared with 8900 feet for the corresponding correct responses.

The correct response data, expressed as the cumulated probability of correct target identification are presented as a function of slant range in Figure 4.

The size of the target presented on the television monitor varied as a function of the target type, its orientation and the slant range. The relationship of target size, expressed in terms of its angular subtense to the observer, to the probability of target identification, is presented in Figure 5.

The number of television scan lines traversing each target in each position and orientation were counted from the face of the television monitor, at slant ranges of 6, 8, 10, 12 and 15 thousand feet. These values are recorded in Appendix C. The values, averaged over each target type, are plotted as a function of slant range in Figure 6.

The data presented in Figures 4 and 6 were combined so as to produce plots of the cumulated probability of correct target recognition as a function of the number of television scan lines traversing the target. These plots are presented in Figure 7.

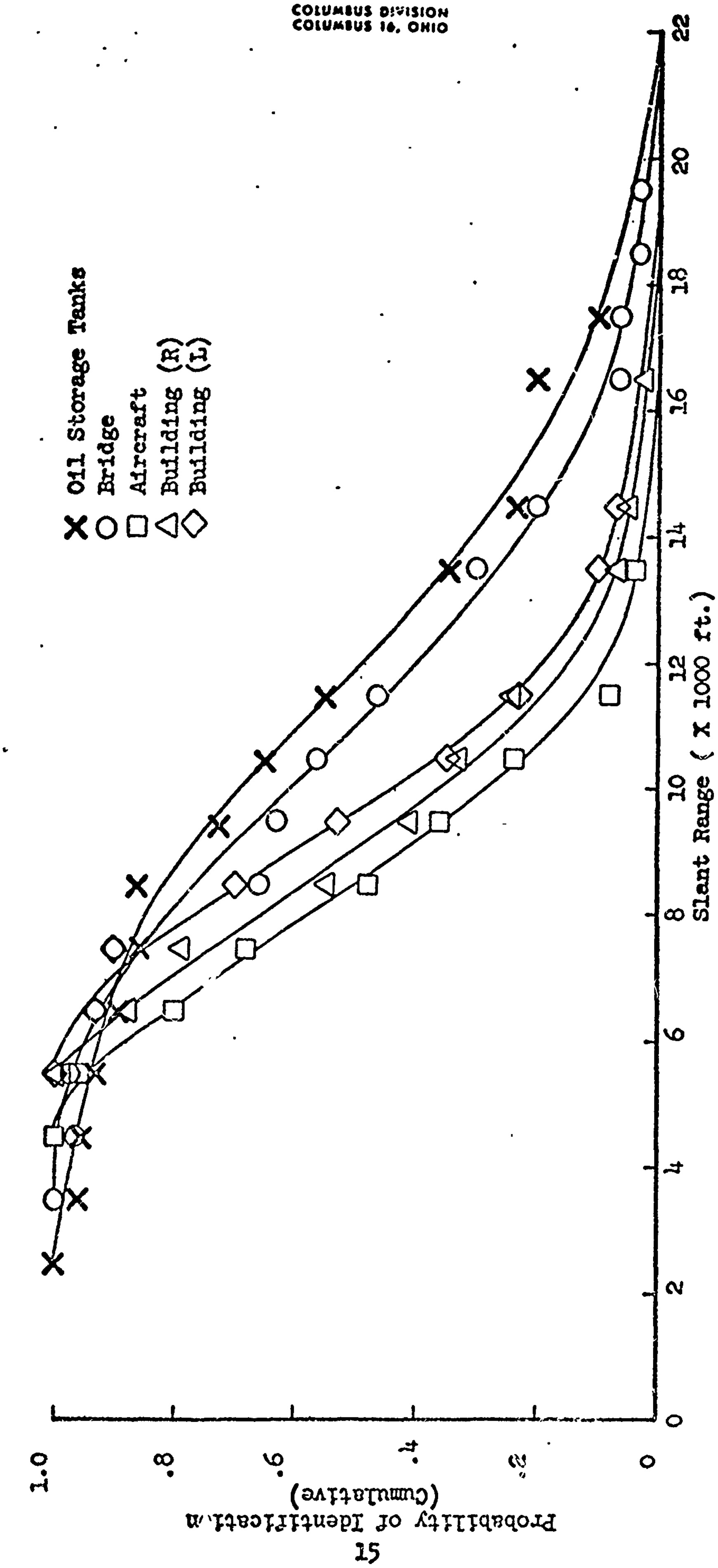

Figure 4

Probability of Target Identification as a Function of Slant Range

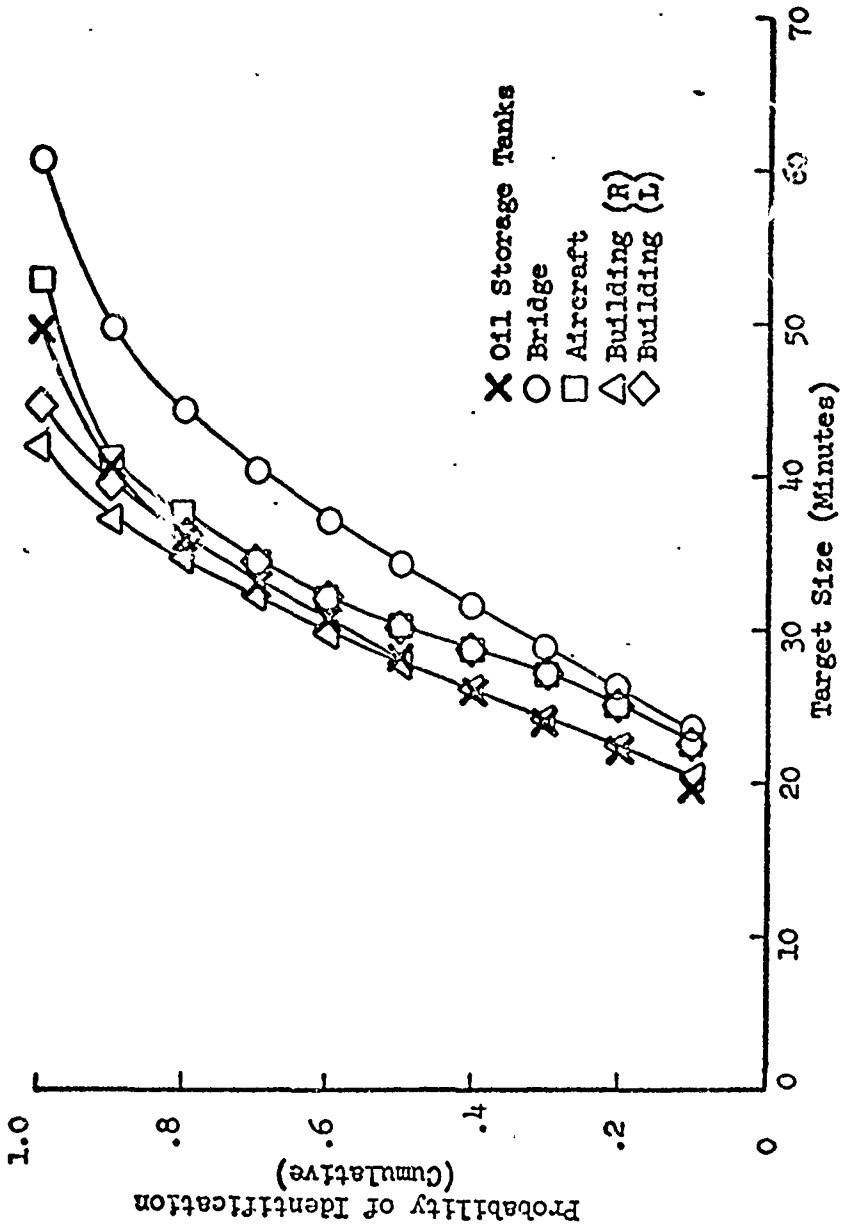

Figure 5

Probability of Target Identification as a Function of Target Size

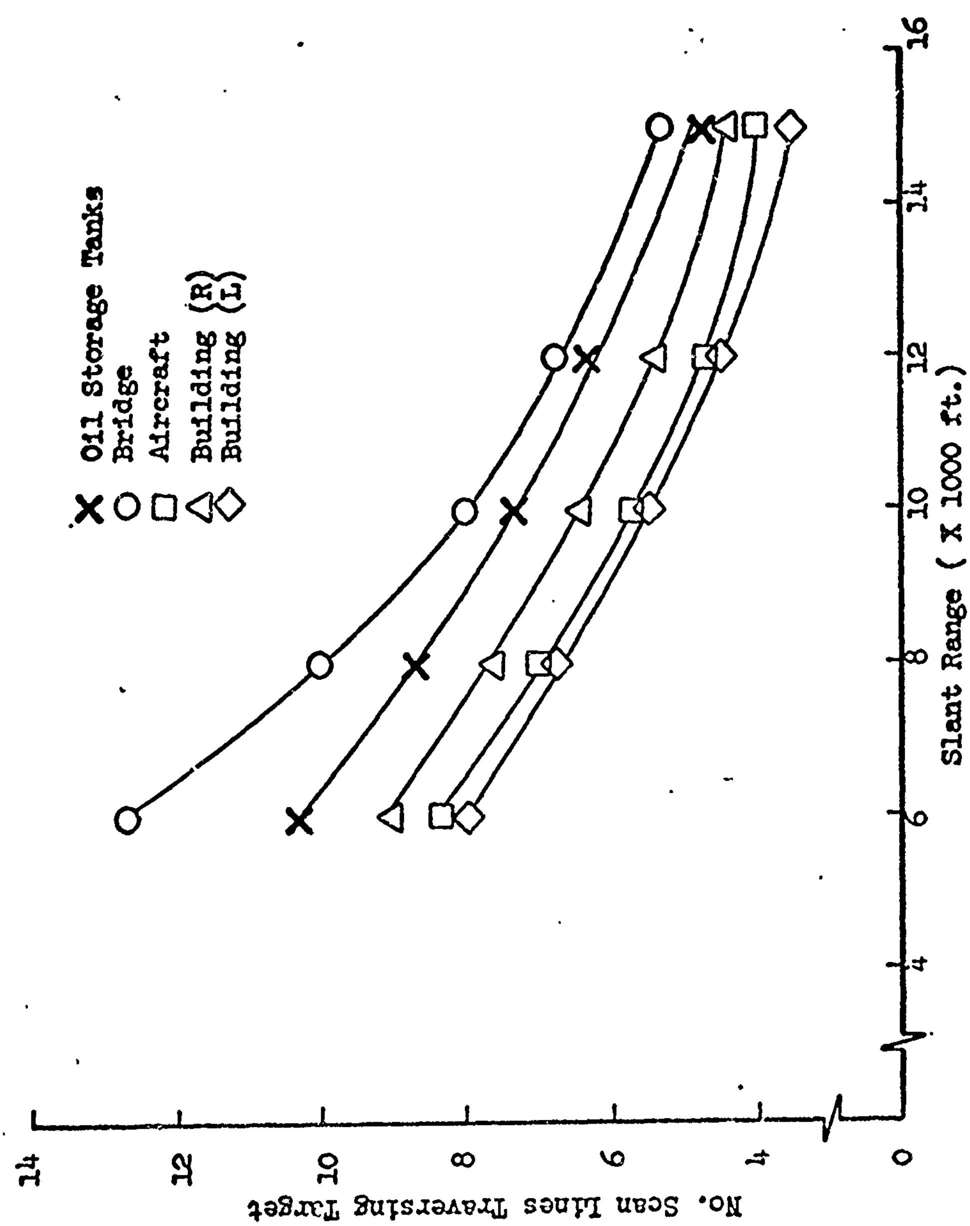

Figure 6

Number of Scanning Lines Traversing Targets as a Function of Slant Range

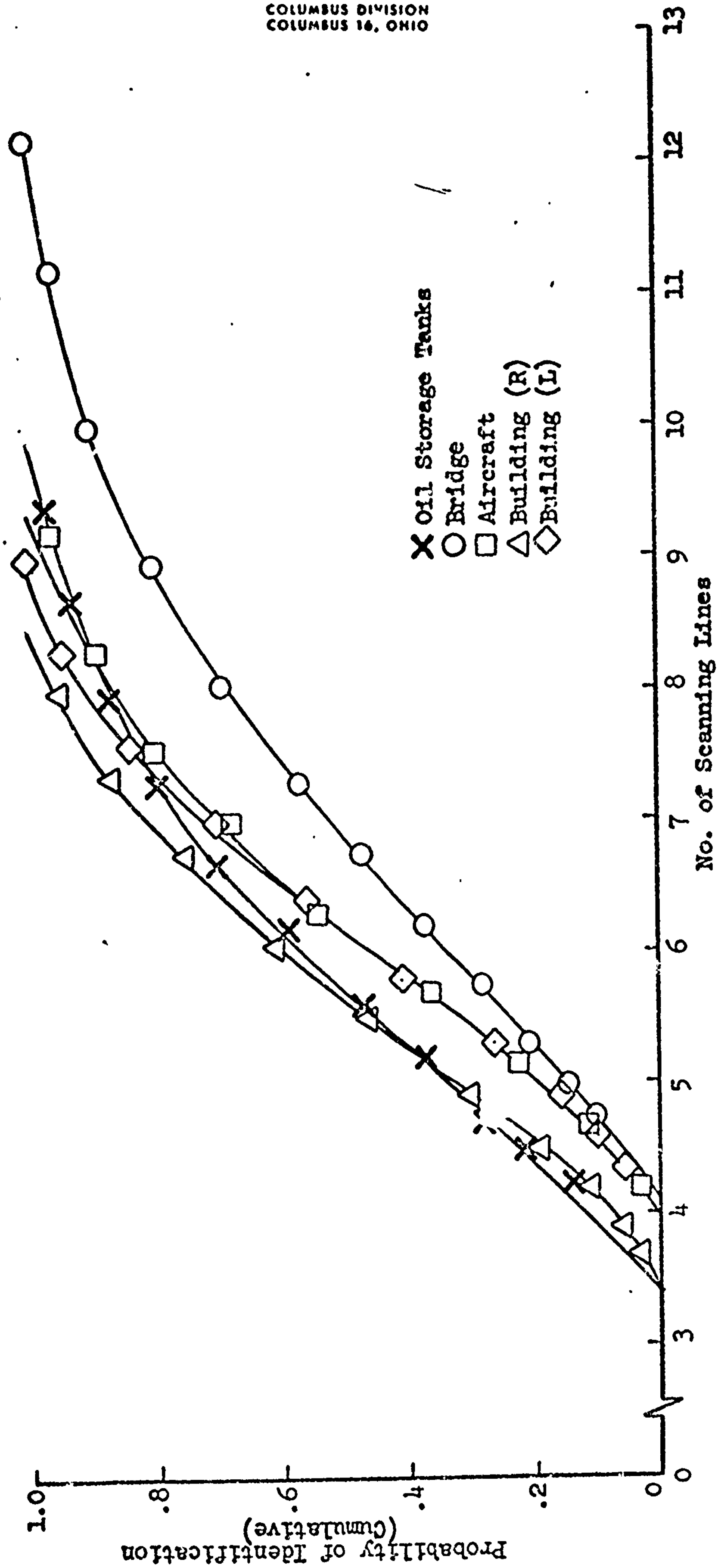

Figure 7

Probability of Target Identification as a Function of the Number of Scanning Lines

DISCUSSION AND CONCLUSIONS

It was previously noted that the incorrect target identification responses tended to occur at slant ranges which were either considerably longer or shorter than the ranges at which correct responses were made. The reason for this pattern of incorrect identifications is not known, but it could be due to the instructions given the observers. As part of their instructions, the observers were told to identify the target as soon as possible; in the case of the incorrect identifications which occurred at the long ranges, the observers may have been attempting to identify the targets before they were sufficiently resolved in an effort to make an early identification. The observers were also told that it was preferable to guess at the identity of the target rather than fail to respond at all. Thus, the incorrect responses which occurred at the short ranges could be due to the observer attempting to guess the target's identity before the end of the "flight", rather than making no response at all. Therefore, both types of incorrect identifications could be due to guessing, which was encouraged by the instructions given the observers.

Although target orientation and target-background contrast were unrelated to identification in the present study, it is obvious that these factors must, in general, have some effect upon identification. The two factors were confounded in the present study, in that the

variation of one was usually accompanied by a variation in the other factor. It is possibly for this reason that the factors, considered independently, failed to relate to identification. If, however, the two factors had been subjected to controlled variation, both would probably have been found to be related to identification.

The probability of target identification was shown to be related to target size. However, it should be noted that this relationship derives from the correlation between target size and the number of scanning lines traversing the target, rather than from the target size, per se. The targets, even at the maximum slant range, were of sufficient size for the observer to identify them, but the lack of resolution (i.e., the number of scanning lines) prohibited their identification. Had there been a greater number of scanning lines, the targets would have been identified at their very smallest sizes (i.e., at the maximum slant range).

The probability of correctly identifying a target was a strong function of the number of television scan lines traversing the target. The functional relationship was approximately linear except at the high probability levels where the function became negatively accelerated. The latter probably resulted, at least in part, from the optical system becoming defocused at the short ranges associated with the high probability levels. The functional relationship was very similar for the five different targets. The most disparate target was the bridge; this

may be attributable to the fact that the bridge differed physically from the other targets in having a "broken" form (deriving from its superstructure) while the other four targets were "solid". The fact that the relationship for the five targets was highly similar, in spite of the considerable differences in the size and shapes of the targets, suggests that the number of scan lines is a fundamental parameter in the identification of targets in television imagery.

There are certain aspects of the present study which should be carefully considered in applying the obtained data. First, the identification task in this study was relatively difficult. The observer was required to perceptually differentiate between targets without making use of contextual information. The latter is usually present in real tasks and may considerably enhance the identifiability of a target. Second, only one approach angle (15° from the horizontal) was investigated; results could differ with different approach angles. Third, the television system had a signal-to-noise level of approximately 35 decibels and a (rated) bandwidth of 8 megacycles. A significant change in either or both of these system characteristics would probably produce results different from those obtained.

RECOMMENDATIONS

In view of the favorable results obtained in this study, and in view of the considerations which must be taken into account in applying these results, further research in this area is desirable. The ultimate aim of such research is to determine the information requirements for acquiring military targets. The initial objective of the further research should be the development of a single index for specifying image quality. This index must subsume the effects which the fundamental system factors (signal-to-noise level, bandwidth and number of scanning lines) have upon image quality. It must also reflect the effects of external factors such as atmospherics. The index must, furthermore, consider the (presented) size of the target, in order to be of maximum practical use. And, the index should be applicable to other types of sensors such as aerial photography.[1]

Once the index is developed, it should be investigated with other target detection, recognition and identification tasks. These tasks should, of course, be investigated with a variety of relevant targets and backgrounds. The effects of briefing and other types of a priori

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[1] Consideration of this problem has led to the tentative selection of an index which appears to satisfy these criteria. This provisional index is the number of "resolving elements" which can be placed within the presented area of the target. A "resolving element" refers to the minimum size detail which is resolved by the system.

information upon performance should also be investigated in order to determine the image quality and information requirements for successively accomplishing the tasks.

APPENDIX A

Slant Range at Identification

This appendix presents the simulated slant ranges at which identification responses were made by each observer. In those instances in which a target was incorrectly identified, the incorrect target response that was made is recorded in the parenthesis following the slant range; the aircraft, oil storage tanks, bridge, building (L) and building (R) are signified by "A", "OT", "BR", "LB", and "RB", respectively. The instances in which an observer failed to make an identification are indicated by "NR". The values recorded at the bottom of each column are the mean slant ranges of the correct identifications. The columns, within each target type, are presented in the order in which they occurred in the random sequence given in Table 2.

Aircraft

	6810	7570	7160
	7940	5510	5790
	8800	5710	9490
	10040	8310	7960
	9460	3420(LB)	6950
	10620	11200(OT)	17650
	10160	11110	8280
	4380	NR	6580
	5450	NR	NR
	9080	10760	13760
$\bar{M}$	8274	8161	9291

Oil Storage Tanks

	8450	11180	11530
	9070	9060	4800
	11001	17300	16390
	8910	10900	5150
	11630	12780	16700
	13100	13330	16570
	NR	8110	12410
	5110	8000	NR
	14120	13600	17420
	10020	10660	19680
$\bar{M}$	10267	11492	13405

Bridge

	12340	13330	9660
	12740	7910	7500
	7240	14140	7780
	14110	13700	10900
	8120	11630	7560
	11810	14990	3560
	7330	7050	11900
	6170	9420	5550
	14120	13600	17420
	10020	10660	19680
$\bar{M}$	10400	11643	10151

Building (L)

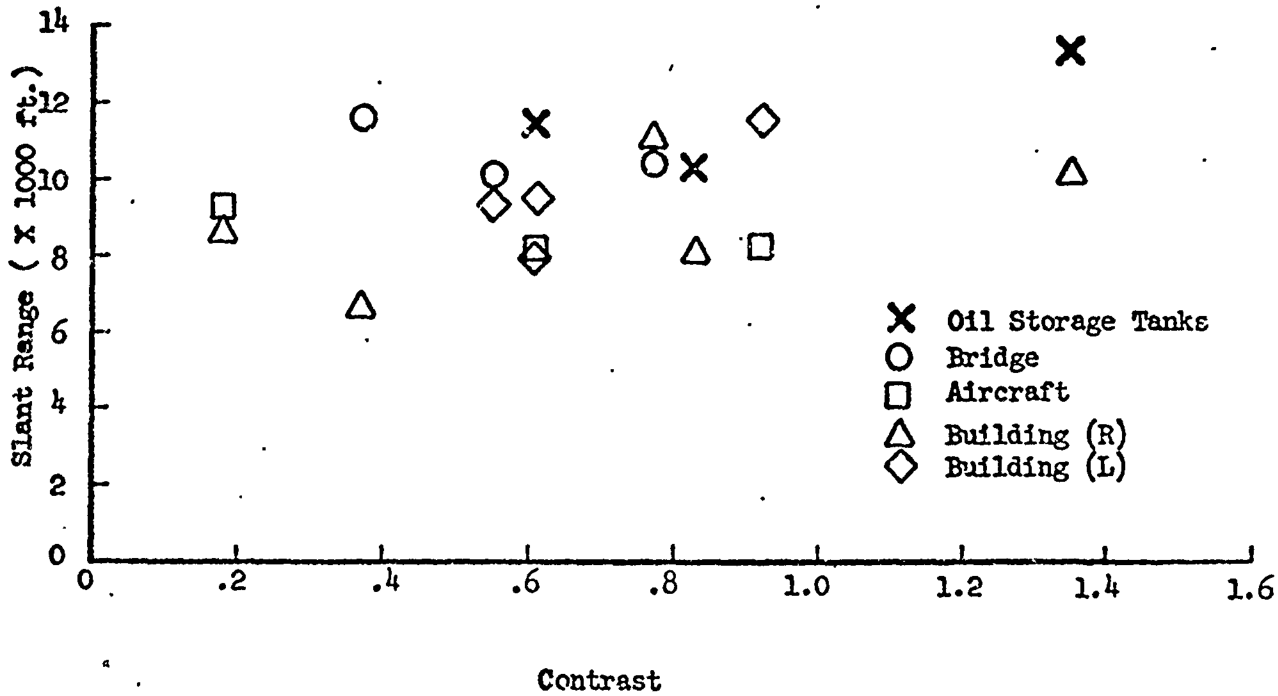
	10320	9600	9580	11180
	5580	5900	7360	6920
	7780	12040(A)	10240	14360
	11040	3420(RB)	7860	10170
	8900	8540	9990	10610
	12880(RB)	7990	11950	15420
	10480	6570(BR)	6570(BR)	8610(RB)
	8360	7440	8810	6110(RB)
	13410	10800(RB)	8870	12680(RB)
	8700(RB)	7890	9420	12250
$\bar{M}$	9483	7893	9342	11558

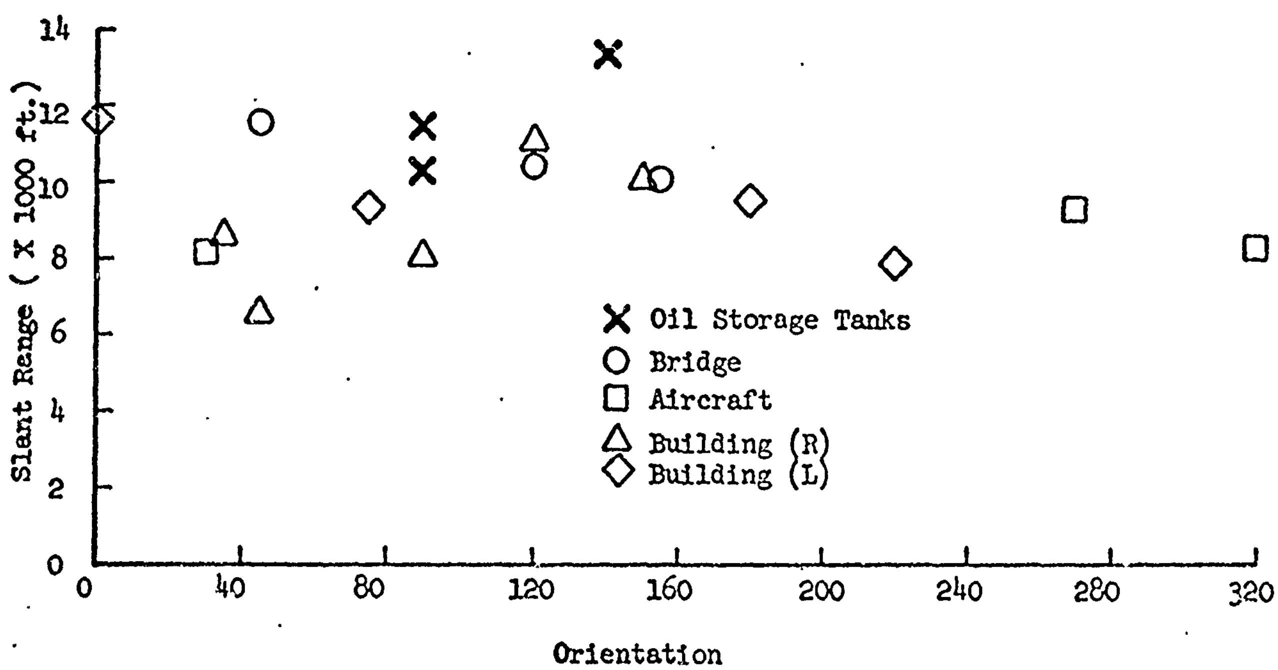
Building (R)

	8350	7610	7710	7590	4260(LB)
	6680	7570(A)	8740	6370	5960(LB)
	9690	7560	10010	19970(OT)	5780
	8820	7750	11970	8930	7970
	7570	13820	11120	12560(OT)	5600
	11920	12390	12620	8700	5350
	4450	15340	11050	9250	7160(BR)
	7530	7000	6960(BR)	6590	4960
	10870	8980	5410(OT)	7970	6250
	10650	11310	16010	9810	10610
$\overline{M}$	8653	10195	11153	8151	6646

APPENDIX B

Target-background Contrast and Target Orientation as a Function of Slant Range at Identification





APPENDIX C

Number of Scanning Lines Traversing Targets

Target		Slant Range (x 1000 ft.)				
		15	12	10	8	6
Aircraft		4.0	4.0	5.0	7.0	9.0
		4.0	5.0	6.0	7.0	8.0
		4.0	5.0	6.0	7.0	8.0
	$\overline{M}$	4.0	4.7	5.7	7.0	8.3
Oil Tanks		5.0	6.0	7.0	9.0	10.0
		5.0	7.0	8.0	9.0	11.0
		4.0	6.0	7.0	8.0	10.0
	$\overline{M}$	4.7	6.3	7.3	8.7	10.3
Bridge		5.0	6.0	7.0	9.0	12.0
		6.0	7.0	8.0	10.0	12.0
		5.0	6.0	9.0	11.0	14.0
	$\overline{M}$	5.3	6.7	8.0	10.0	12.7
Building (L)		3.0	4.0	5.0	7.0	8.0
		4.0	5.0	6.0	7.0	8.0
		3.0	4.0	5.0	6.0	8.0
		4.0	5.0	6.0	7.0	8.0
	$\overline{M}$	3.5	4.5	5.5	6.75	8.0
Building (R)		5.0	6.0	7.0	8.0	9.0
		4.0	5.0	6.0	8.0	10.0
		3.0	4.0	5.0	6.0	8.0
		6.0	7.0	8.0	9.0	10.0
		4.0	5.0	6.0	7.0	8.0
	$\overline{M}$	4.4	5.4	6.4	7.6	9.0

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